Sándor NAGY[1] – Sándor SEMPERGER[2]

ADVANCED AND SECURE POWER SUPPLY FOR GUARDING BORDERS

HATÁRVÉDELEM FOKOZOTTAN BIZTONSÁGOS ÁRAMELLÁTÁSA

HTTPS://DOI.ORG/10.30583/2024-1-2-176

Abstract

The national border security needs include, in addition to armed deployment of forces, the provision of full-scale health and medical care, as well as the provision of life necessities for official service elements. One of the highest priorities in this respect is the provision of advanced and reliable power supply to deployed military camps. Once a reliable, full energy supply is established for the long term, comprehensive military service can be implemented. For rapid deployments, the power supply is delivered by generators, which provide a reliable backup system in addition to the established permanent power networks. To stabilize the security system, a multi-level energy network is needed, manifesting in a synchronous generator. Several potential options were considered to increase the reliable supply of electric power and generator efficiency essential for this requirement.

Keywords: synchronous generator, safety, area of coverage

Absztrakt

Biztonságvédelmi szükségletünk magába foglalja a fegyveres kivonulások mellett a teljes egészségügyi, orvosi ellátás biztosítását, a szolgálatban lévő hivatalos szervek életszükségleteinek ellátását. Ennek egyik

[1] Sándor Nagy PhD student, Óbuda University Doctoral School on Safety and Security Sciences, Budapest, Hungary. Contact: nagy.sandor@celitron.com https://orcid.org/0009-0004-0790-5758

[2] Sándor Semperger PhD, Department of Automation Óbuda University - Kandó Kálmán Faculty of Electrical Engineering Budapest, Hungary semperger.sandor@uni-obuda.hu ; https://orcid.org/0009-0006-3224-2313

legkimagaslóbb pontja a mobilis katonai táborok áramellátásának a kiszolgálása. A hosszútávra fokozottan biztosított megbízható, teljes energiaellátás mellett kivitelezhető a teljeskörű katonai szolgálat. Az energiaellátást egy mobilis rendszerben a generátorok biztosítják, melyek megbízható hátteret szolgáltatnak a már kiépített energiahálózatok meghibásodása esetére is. A biztonsági rendszer stabilizálásához többlépcsős energia hálózat szükséges, mely végső pontja egy szinkrongenerátor. A generátor biztonságos rendelkezésre állásának és hatékonyságának növelése érdekében különböző vizsgálatokat végeztem.

Kulcsszavak: szinkron generátor, biztonság, térerősség

Introduction

In Hungary today, the focus should be placed on securing the national borders. The need for these measures is precipitated by the immigration crisis in Europe (also known as the European refugee crisis). The causes of the immigration crisis could be attributed to armed conflicts, political and religious persecution, as well as economic hardships.

The migration exodus has had a profound effect on Hungary. To this day, there is a need to maintain an advanced state of readiness to protect the national borders. In addition to the illegal immigration problems, the invasion of Ukraine by Russia on February 24, 2022, further intensified the requirement for more pronounced national border security[3].

Public safety, social morality, and foreign power covert threats increasingly play a dominant role in influencing the risk level of the national social and economic stability of the country. The increased appearance of natural and human-caused risk factors exacerbates the overall threat. In the detection, prevention, and management of such adversities, developments and innovations in the fields of information technology, engineering, and electrical engineering provide potential solutions for more rugged management measures and responses to the above-listed challenges. Online platforms and networks now play a central role in the prevention, enabling quick and efficient tracking and elimination of unwanted events. Today's technical capabilities allow

[3] Source: https://www.economx.hu/kulfold/haboru-ukrajna-oroszorszag-2-eves-evfordulo-adatok. Visited: 02.04.2024

communities affected by disasters to participate actively in preparedness and response.

For emergency responses, a continuous power supply needs to be available in the affected areas. In deployed military operations, the power supply is currently provided by diesel generators[4]. The power generator is a special electric power source that keeps the electric current flowing through to the consumption points at a steady rate. The generator maintains a constant flow of electrical power regardless of the prevailing temperature, resistance in the distribution network, or other impeding factors.

The security of technology necessitates adherence to several critical conditions. These conditions include:

- modular system applicability,
- flexible use,
- transportability,
- reliability; and,
- capacity.

In the current plans, a 4500 kVA diesel generator can provide the basic power supply for a camp of 300 people. Plans include increasing the number of people to 1200[5]. In view of this requirement, an examination was conducted of the current iron material content of the generators and the efficiency of the permanent magnets.

The electric energy structure supply based on the generators of the ground defense forces[6].

The initial power generation plans of deployed military operations were implemented in the 80s and are still in practice today - virtually

[4] Source: *https://epa.oszk.hu/02700/02735/00083/pdf/EPA02735_katonai_logisztika_2016_ksz_102-132.pdf pp. 109.*

[5] Source: *https://epa.oszk.hu/02700/02735/00083/pdf/EPA02735_katonai_logisztika_2016_ksz_102-132.pdf pp.108.*

[6] Source: *https://tudasportal.uni-nke.hu/xmlui/bitstream/handle/20.500.12944/21419/vegvari_zsolt_doktori_ertekezes.pdf pp. 44.*

unchanged. The diesel engine generators are the most reliable electric power-generating sources, in addition to being the most dependable. These generators are fully deployable and suitable for quick relocations. These devices are single-phase for smaller power requirements, but for higher energy needs, a three-phase structure is used. To provide adequate electric supply for deployed forces, field electrical networks utilizing diesel generators were designed.

The generators used by the Hungarian Defense Forces are designed to provide 230/400 V voltage at 50 Hz frequency, which could be modified based on the requirements. For single-phase connection, they offer a maximum of 16 A "F" type protective contact "schuko" sockets**. Figure 1** depicts elements of a field network illustrating the electrical structure setup of the CL15 - international exercise - held in Várpalota:

- Yellow diesel generator (To the left of the white control container).
- Electrical distribution cabinet (to the right of the diesel generator – green –).
- "Bálvány" (On the left in the foreground is the so-called "bálvány" where the users of the generated electricity are connected).

Figure 1. Prepared electrical network details on the CL15 international logistics exercise.[7]

[7] Source: Végvári Zsolt: A HIBRID VILLAMOS ENERGIAELLÁTÓ RENDSZEREK VEZÉRLÉSÉNEK TEREPI MEGVALÓSÍTÁSA. Hadmérnök, XI.Évfolyam 4. szám-2016 december. pp. 3.

In the current state of the military, there is a need to develop the electrical network of the Hungarian Defense Forces further to ensure a better, more secure, and adequate power supply for ground forces. For the implementation of this process, it is recommended that the performance and lifespan of the generators be improved. The recommendation further includes reducing the number of specialists needed to operate and maintain the generators. The energy-technical structure composition of the generators is a priority focus for the country's ground forces, as they usually do not keep readily available replacements in reserve for the electric power-generation devices in the camps.

DEPLOYED MILITARY CAMPS ENERGY REQUIREMENT A high priority in tasking deployable ground forces to the operational theatre is to ensure adequate provisions for their total electrical power requirements. The planning process must consider the austere environment, which lacks an established energy source infrastructure. Thus, the planning process must ensure the provision of an adequate electric power supply source for the camp's military networks. Points for consideration in providing the necessary electric power supply include:

- Deploying forces must be self-sufficient in producing their electrical power, which is required to operate in an austere environment.
- Security measures must include the necessary provisions to back up energy sources.
- Location and organization of the selected camp, its structural construct, and the establishment of the electrical network.
- Emphasis on reducing possible errors.

The potential deployment camps were examined and determined that they have to provide fuel for two types of energy users — fuel for the vehicles and electrical power generators to supply the energy requirements of the systems listed above. The necessary fuel for the camp's operation is transported to the site by logistic forces, which is one of their priority tasks. NATO has already implemented the single-fuel concept for ground forces, which was determined to be kerosene, identified as F-34[8] [**Figure 2].**

[8] Source:https://www.nato.int/docu/logi-en/logistics_hndbk_2012-en.pdf pp. 96.

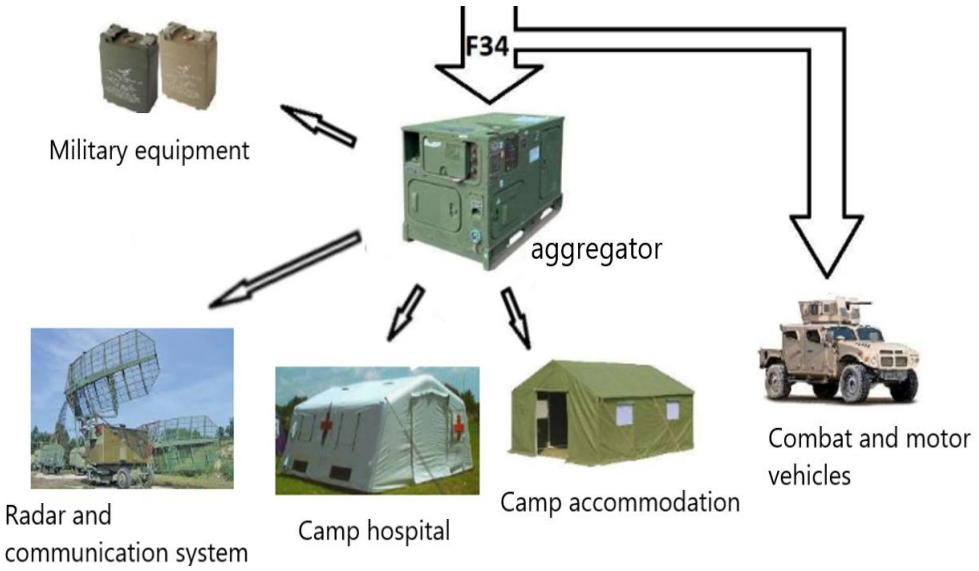

Figure 2. Energy distribution of a deployed forces camp
(The author's figure)

The rapid overall technological advances have profoundly impacted the armed service, which manifests in an increased demand for electric energy. **[Figure 3]**

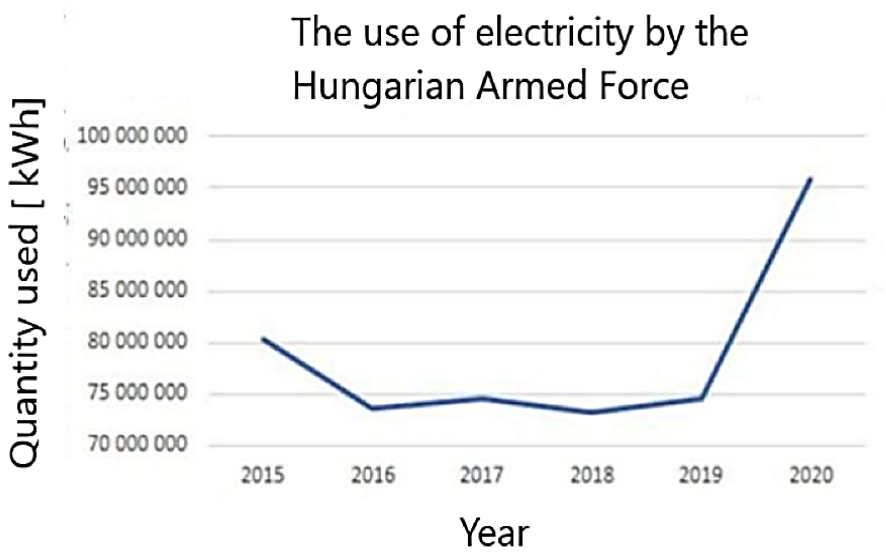

Figure 3. Electric energy usage of the Hungarian Defense Forces[9]

Hungarian Defense Forces' electric power supply unit

The following is a typical illustration of the basic structure of a diesel-generated electric power system used by the Hungarian Defense Forces[10].

The deployable electric power generator permanently operates on a kerosene (NATO marking F-34) type of fuel. The entire deployed camp energy source is based on this fuel type. Since this type of electric power generation supplies the camp as a whole, it is necessary to ensure that the power supply is provided in several stages. The system construct should take into account not only the optimal requirements for the deployed camp operation but must also include provisions for emergency reserves.

[9] Source: https://tudasportal.uni-nke.hu/xmlui/bitstream/handle/20.500.12944/21419/vegvari_zsolt_doktori_ertekezes.pdf pp. 25.

[10] Source: What are the parts of diesel generator and its functions | by OTC Power | Medium

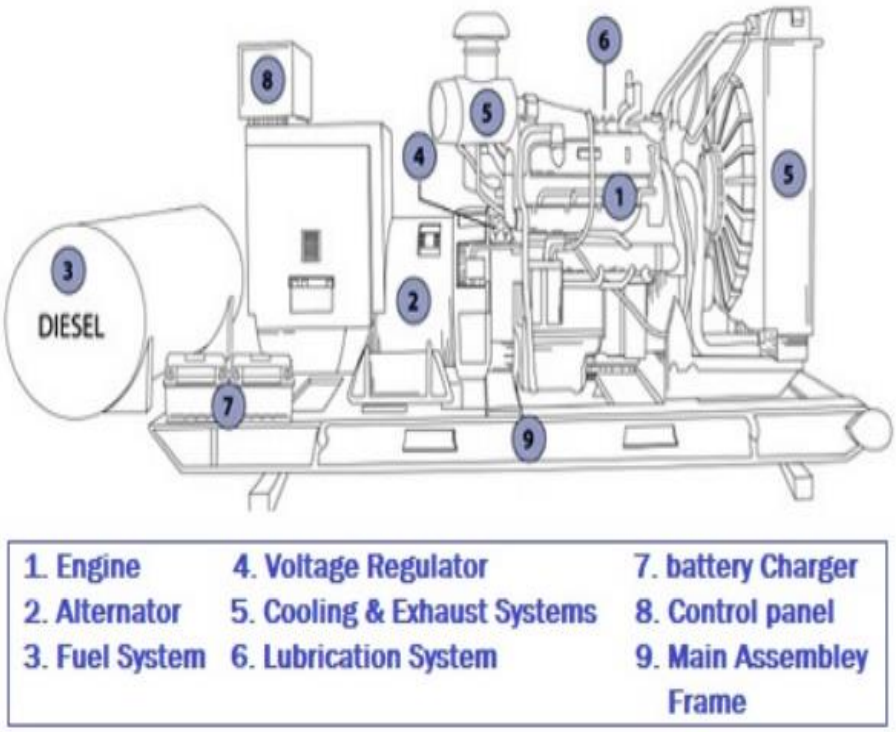

Figure 4. The main parts of the diesel generator[11]

The most suitable for this task is the diesel generator and its main components consisting of **[Figure 4]**:

- Engine,
- Alternator,
- Fuel system,
- Voltage regulator,
- Cooling and exhaust system,
- Lubrication system,
- Battery Charger,
- Control panel, and
- Main assembly / Frame.

Diesel engine:

[11] Source:https://www.coopalpower.com/diesel-generator-power-generation.html

This type of electric power generator consists of a diesel engine and a generator. The diesel engine drives the generator to produce electric power. The basic structure of the diesel engine consists of, inter alia, a cylinder, piston, cylinder head, intake valve, exhaust valve, connecting rod, crankshaft, bearing, flywheel, and other components. The generator's source of power is usually a single or multi-cylinder four-stroke diesel engine. For illustration purposes, the basic operating principle of a single-cylinder, four-stroke diesel engine will be discussed. The diesel engine could be started manually or by cranking the engine so that the piston moves up and down in the upper closed cylinder. The piston cycles through four strokes (phases): intake, compression, combustion and work (expansion), and exhaust. When the piston moves up and down, the intake valve opens, and fresh air filtered by the air filter enters the cylinder to complete the intake stroke. The piston moves from bottom to top, the intake and exhaust valves close; the air is compressed, the temperature and pressure rise, and the compression process is completed. When the piston reaches the top, the fuel injection valve sprays the filtered fuel into the combustion chamber in the form of a mist. It mixes it with high-temperature and high-pressure air to ignite and combust immediately. The resulting high pressure pushes the piston downward, rotating the crankshaft, and thus completes the work stroke. After the work stroke is completed, the piston moves downward, and the exhaust valve opens to expel the exhaust gas and complete the exhaust stroke. The crankshaft rotates half a turn per stroke. After several work cycles, the diesel engine gradually accelerates under the inertia of the flywheel.

Generator:

As the crankshaft of the diesel engine rotates, it drives the generator to rotate and produce electrical energy. The generator contains a DC generator and an AC generator. The generator consists of a generator housing, magnetic poles or iron cores, three-phase symmetric winding on the stator, and the rotor can be an excited electromagnet (slip ring rotor or brushless rotor solution). The operating energy production principle manifests when the diesel engine rotates the rotor part of the generator/synchronous machine. As a result, voltage is induced in the winding of the stator, which can be 50 Hz or another frequency, and users can be provided with appropriate voltage stability based on their requirements. The generator consists of a constant magnet of a given number of poles (rotor), which are made of magnetic materials with alternating north and south poles and armature coils consisting of an iron structure (stator parts). The stator parts are strung with several

series coil groups. The following operating energy production principle prevails: The angular velocity required for the magnitude of the induced voltage is provided by the rotor of the diesel engine. The alternating magnetic field is formed in the winding in the stator by the alternating magnetic poles. The symmetric winding creates voltages offset by 120 degrees.

Control panel:

This panel controls the generator's operation. The controlling functions include the start button, a frequency switch, an engine fuel indicator, a temperature indicator of the coolant, and more. The control panel provides the user with a visual display of the generator's operating status and enables the operator to input controlling variations into the system's workings directly. The control panel starts and terminates the generator operation. It also monitors the engine and alternator, indicating normal operation status or the need for maintenance and control. The control panel ensures the general system functions correctly. The control panel also provides the ability to synchronize the system's parallel work activation.

Voltage regulator:

In order to protect the electrical equipment and maintain its normal operation, the current produced by the generator must also be regulated and controlled by the regulator.

The voltage regulator is the most complicated component of an electric generator. This part has a monitoring purpose, which regulates the voltage output.

Ensuring the generator produces electricity at a consistent and stable voltage is essential. Without a voltage regulator, significant variations could occur based on the engine speed. The electronic monitors are unable to manage such irregular power input and, as such, must be supplemented by a voltage regulator. Thus, the main function of the voltage regulator is to maintain a consistent and standardized power supply.

Fuel system:

The power source is responsible for ensuring a stable and consistent supply of electricity. Without a voltage stabilizer, there can be significant fluctuations in the power supply, depending on the speed of the generator, making it challenging for electrical appliances to function

properly. Therefore, the purpose of this component is to maintain a constant and reliable power flow for use by all devices.

The fuel delivery system typically comprises a fuel tank connected to the engine through a pipeline. In this setup, diesel is directly fed to the engine to initiate the process described above. The capacity of the fuel tank ultimately determines the generator's operational duration.

A variety of quiet enclosure generators often come equipped with fuel reservoirs located at the base of the unit. If a larger fuel capacity is necessary, a custom extended base fuel system can be designed and manufactured, or the generator can be connected to an external standalone bulk fuel tank (enclosed in a steel or plastic casing to reduce noise levels).

For larger power generator plans that need the genset to be placed into an acoustic room, separate fuel systems are normally located either inside or beneath the room or sometimes both.

Cooling system and exhaust system:

The primary role of the cooling system is to prevent the generator from reaching high temperatures. It involves circulating coolant within the generator to counteract the excess heat generated by the engine and alternator. Subsequently, the coolant transfers this heat through a heat exchanger and expels it outside the generator. The exhaust system functions similarly to the exhaust in vehicles. It collects any gases emitted by the diesel engine, guides them through a piping system, and expels them from the generator.

Lubrication system:

The lubrication system is a part that connects to the engine and pumps oil into it to ensure every part works friction-free and does not grind against other parts. Without a suitable lubrication system, the machine will break down.

Battery charger:

A diesel engine requires a tiny electrical motor to help put it into action. The small motor works with a battery, which needs to be charged.

Construction of AC synchronous generator (alternator)[12,13]

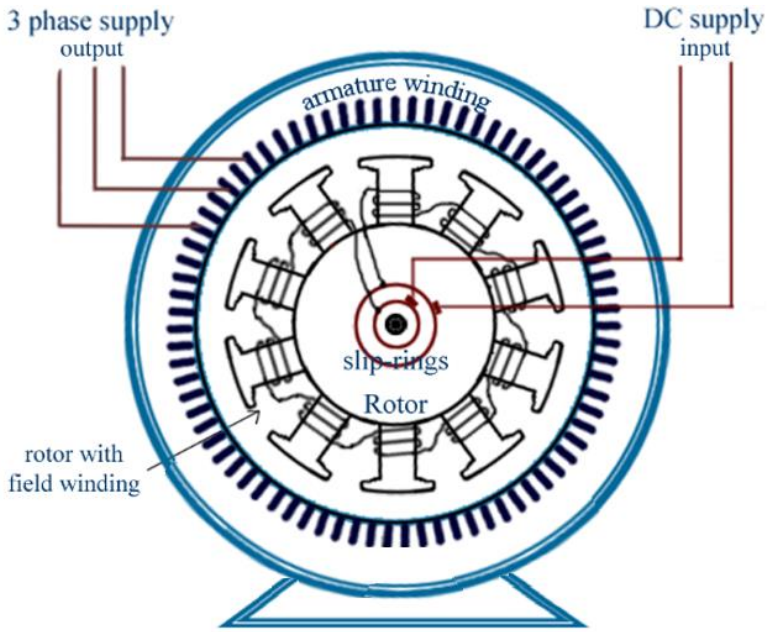

Figure 5. AC generator cross-sectional model basic diagram[14]

Armature: The armature consists of a 3-phase symmetric winding.

Rotor: The rotor consists of an excitation coil, which can be an electro-magnet or a permanent magnet, depending on the energy density we want to achieve.

Armature winding is stationary in an alternator.

- At high voltages, it is easier to insulate the stationary armature winding, which may be as high as 11 kV or even more in some cases.
- The high voltage generated can be extracted directly from the fixed armature. In contrast, with a rotating armature, there may be a wider

[12] Source : https://www.brown.edu/Departments/Engineering/Courses/ENGN1931F/AC_Electrical_Generators_ASOPE.pdf

[13] Source : https://www.electricaleasy.com/2014/02/AC-generator-alternator-construction-working.html#google_vignette

[14] Source: https://www.electricaleasy.com/2014/02/synchronous-motor-construction-working.html

brush contact area, resulting in a voltage drop at higher levels, along with the challenge of managing sparking at the brush surface.

- If the field exciter winding is located in the rotor, the excitation voltage DC can flow through the brushes and slip rings.
- The armature winding can be braced well to prevent deformation caused by high centrifugal force if it is in the rotor.

Rotor: There are two types of rotors used in an AC synchronous generator/alternator: (1) Salient and (2) Cylindrical type

1. Salient pole type: Salient pole design is utilized in alternators operating at low and medium speeds. The diagram above illustrates the structure of an AC synchronous generator with a salient pole rotor design. This rotor type comprises numerous projecting poles attached to a magnetic wheel. These poles are also laminated to minimize the eddy current losses. Generators employing this rotor design charlatanically have a wide diameter and short axial length.
2. Cylindrical type: Cylindrical type rotors are used in high-speed alternators, particularly in turbo-alternators. This design of the rotor consists of a smooth and solid steel cylinder with slots along its outer periphery. Field windings are placed in these slots.

A DC supply is given to the rotor winding through the 'slip-rings and brushes' arrangement.

Connecting an alternator in the grid is called synchronization of the alternator.

Operation and maintenance of the generator

A comprehensive examination is required for the selection and operation of the generator providing the power supply; in summary, attention should be paid to critical details.

The most important question is, what devices will the generator supply with energy?

In the first step, we have to start by listing all the devices that will be connected to the generator. It is important to determine the total

wattage required by these devices so that we can calculate the minimum power input needed for the generator.

Based on the data, it is possible to determine the system's 100% nominal energy requirement. However, a complete system does not use the apparent power, so it is worth calibrating the obtained energy requirement to the generator's 80% capacity performance.

This statement was also determined by the international standard with the generator's power factor of 0.8, but with suitable excitation, the value **one** can also be reached.

Figure 6. Generator power factor[15]

The next step, as a priority consideration, is the running requirement.

Will the generator be a standby asset or the primary electrical power source?

The environmental aspect should be considered as the next point of examination. The conditions of the site to be installed and the possibility of access must be analyzed. It should also be analyzed whether the installation of the planned electrical system is feasible based on the operating conditions at the location.

[15] Source: https://powerelectrics.com/blog/generator-sizing-a-step-by-step-guide

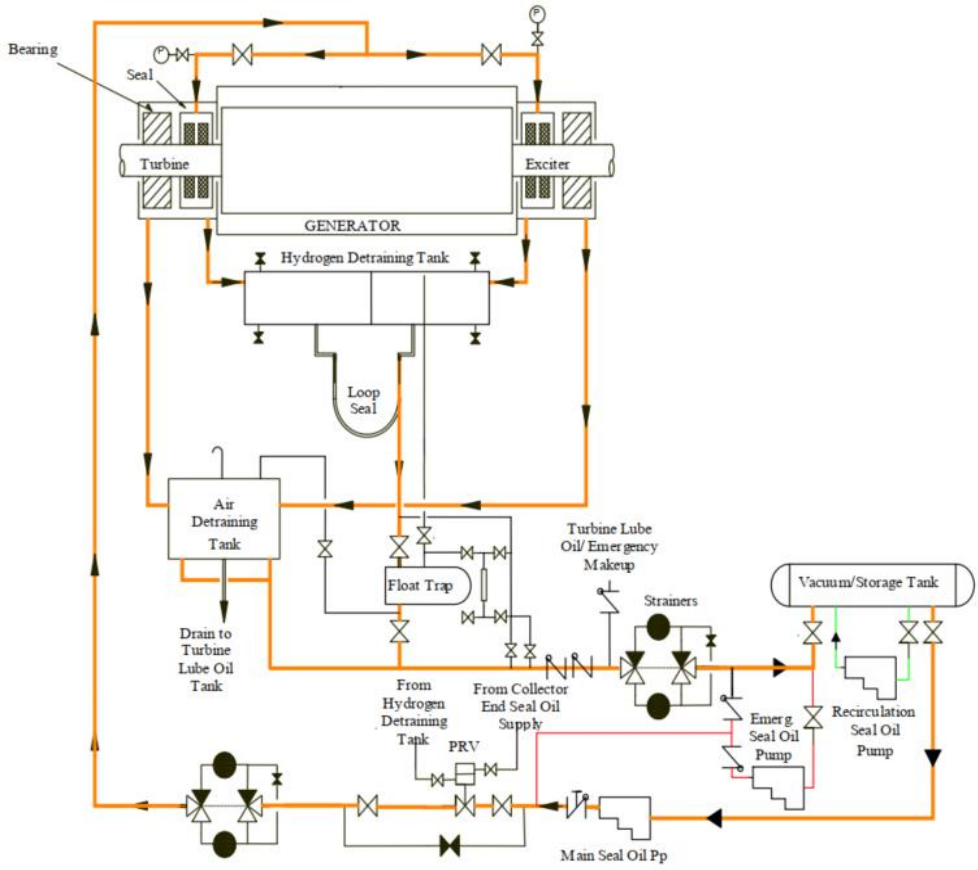

Figure 7. Generator seal oil system simplified diagram[16]

Taking into account the prevailing environmental conditions at the potential deployment site and the demands on the generator, special attention must be given to the following elements:

- Determination of the number of poles of the generator [17,18], which gives its operating speed and area of coverage:
  - In the case of a 2-pole generator, 3000 rpm /min corresponds to the 50Hz frequency range.
  - In the case of a 4-pole generator, 1500 rpm /min meets the 50Hz requirement.

[16] Source: https://www.brown.edu/Departments/Engineering/Courses/ENGN1931F/AC_Electrical_Generators_ASOPE.pdf pp. 42.

[17] Source: https://www.hobbielektronika.hu/forum/getfile.php?id=292532

[18] Source: https://powerelectrics.com/blog/generator-sizing-a-step-by-step-guide

- The oil circuit of the generator.

A cooling circuit is to be provided according to the environment in which the power source is to be installed and the anticipated loading of the generator.

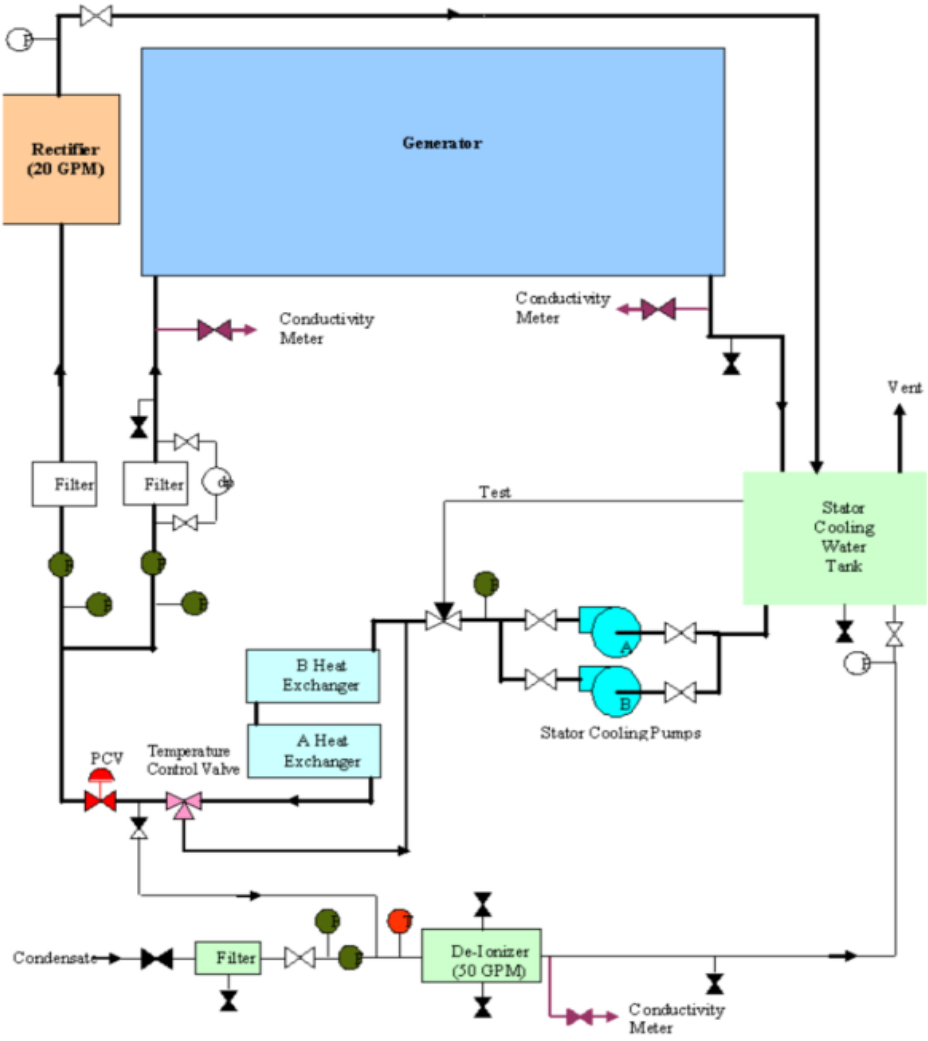

Figure 8. Stator cooling system diagram[19]

[19] Source: https://www.brown.edu/Departments/Engineering/Courses/ENGN1931F/AC_Electrical_Generators_ASOPE.pdf pp. 48.

The electric power supply requirement of a 1200-person camp

The current plan referred to earlier requires 4500kVA energy for 300 persons. Looking into the future, the development of a 1200-person camp is the set goal, which, in terms of numbers, can determine an energy requirement of 13500 kVA.

The 13500 kVA electric power requirement must be validated with the deployed camp's mission and its allocated equipment. The camp's assigned mission and equipment holdings have a profound impact on electrical power consumption.

In this example, the camp's proposed structure is presented. One of the highest emphasis will be placed on the reserve power supply source within the construction of a secure power generation network.

The proposed system is based on the allocation of four diesel generators, which are placed far from each other for safety reasons. The generator dispersion within the camp aims to prevent external hostile action or, in case of internal failure, provide adequate safety distance between the generating sources.

Figure 9. 3500kVA diesel aggregator[20]

[20] Source: https://www.pon-cat.com/en-nl/products/cat-power-generation/emergency-power/cat-3516e-50-hz-2

In the construction of the camp, the power supply must be prioritized, and units must be limited to those minimal forces essential for the discharge of the mission. Based on the research conducted, two units were identified for priority consideration: health care and communication assets. These prioritized units' power supply requirements are to be continuously provided by two generators. Both of these dedicated generators are to be located far apart and joined together with a redundant connection. When functioning, one generator only provides a secondary power supply. Still, each generator should be capable of delivering the full power supply requirement by itself to the two priority modules **[Figure 10]**. As soon as one generator stops operating and goes into an out-of-service state, the system automatically switches to the second power source without delay.

The two remaining generators provide additional power supply to the deployment camp. These two generators can be switched manually to meet the other units' supply requirements - if needed. The prerequisite for this is the coordinated and synchronized operation of the generators, which can be addressed adequately with modern controllers. During the operation of the generators, the controller monitors the main operating parameters. Should technical problems occur during normal operations, the control panel immediately signals an error. Should it be necessary, such errors can be displayed at a remote supervisory station.

The following are the typically used markings, alarms, and parameters for generators.

- Oil pressure.
- Coolant temperature.
- Fuel level.
- RPM.

The recommended system design would be based on a dual bus AC main distributor; the diesel generators feed into this main distributor, and users connect at this point; due to the dual bus design, all consumers and generators can be connected into one system, so electric power is provided to all users at the same time. Separate power networks can also be set up outside of the described network construction with their designated groups and their electric power generators.

The control of the AC main distributor and the control of the diesel generators must be highly synchronized so that synchronous interruption-free switching can be achieved on the alternating current.

The controllers can be widely adapted to consumer needs when properly programmed.

A continuous automatic electrical connection system is not recommended between all generator networks. The goal is to isolate any malfunctions from the other power supply units.

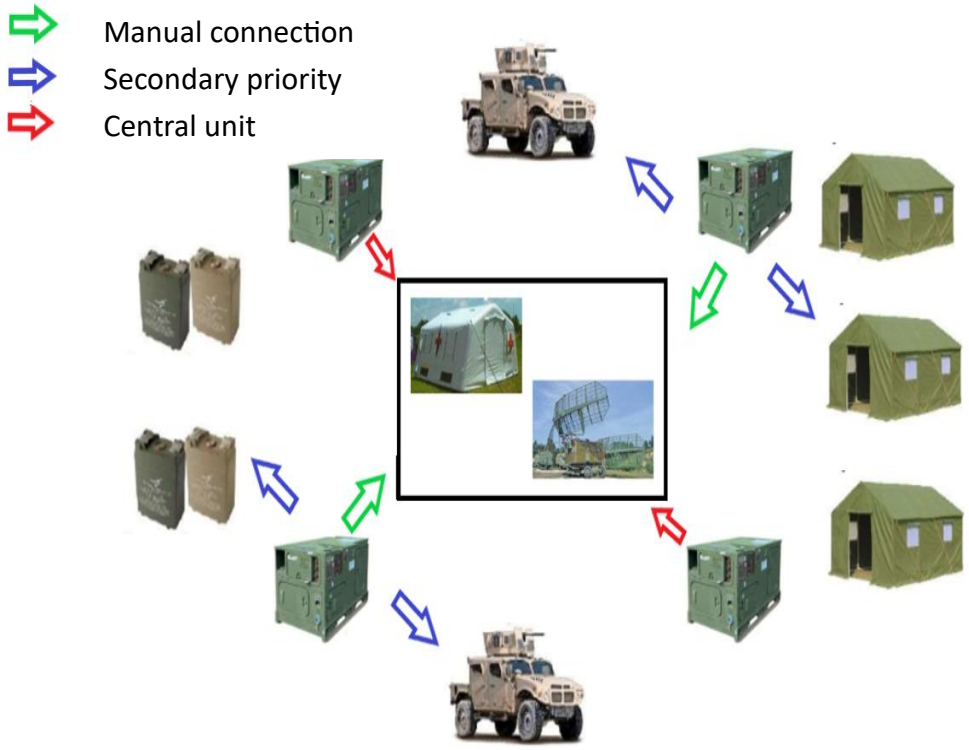

Figure 10. Distributed power supply at a 1200-person military unit (The author's figure)

Conclusions

The research undertaken presents database points that contribute to the development of electric power generation by the Hungarian Defense Forces. Some platforms also provide information for further

development activities, which contribute more to the continuation of security activities.

The basis of this article's research supports the establishment of security developments arising from the increasingly escalating hostile situation today in the operation of deployed camps. Under these circumstances, the transformation and development of a safe and reliable electric power supply ensure the successful establishment of varying-size deployment camps and their personnel, representing different functions and electric power requirements.

Given the various electric power supply units, including reserve generators, the central unit of a deployed base receives increased electric supply to ensure the energy demand of the communication and health units is adequately addressed.

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